

What is claimed is:

1 1. A microlithographic reduction projection catadioptric
2 objective (100, 200) comprising in sequence from an object side to an image side
3 of:
4 a catadioptric group (G1) for providing a virtual image, wherein
5 the catadioptric group (G1) comprises a reflective field group and includes a
6 folded off-axis field geometry; and
7 a dioptric group (G2) for receiving the virtual image and providing
8 a real image.

1 2. A microlithographic reduction projection catadioptric
2 objective (100, 200) comprising:
3 a catadioptric group (G1) including a reflective field group for
4 providing a virtual image, wherein the reflective field group is arranged in a
5 folded off-axis field geometry to fold light such that object and image planes are
6 parallel to one another and perpendicular to an optical axis to enable unlimited
7 scanning in a step/scan lithographic configuration; and
8 a dioptric group (G2) for receiving the virtual image and providing
9 a real image.

1 3. An objective (100, 200) as in any preceding claim, wherein
2 the catadioptric group (G1) includes at least three lens elements (E1-E3).

1 4. An objective (100, 200) as in any preceding claim, wherein
2 the catadioptric group (G1) includes three mirrors (M1-M3) and two flat folding
3 mirrors (F1, F2).

1 5. An objective (100, 200) according to claim 4, wherein two
2 mirrors (M2, M3) are positioned downstream of the two flat folding mirrors (F1,
3 F2).

1 6. An objective (100, 200) according to claim 5, wherein the
2 two mirrors (M2, M3) downstream of the two flat folding mirrors (F1, F2)
3 comprise a concave mirror and a convex mirror, respectively.

1 7. An objective (100, 200) according to claim 6, wherein the
2 convex mirror (M3) is the most image forward mirror.

1 8. An objective (100, 200) according to claim 4, wherein one
2 of the folding mirrors (F2) is upstream of the most image forward lens element
3 (E2) of the catadioptric group (G1).

1 9. An objective (100, 200) according to claim 4, wherein the
2 most image forward folding mirror (F2) is disposed between a second lens
3 element (E2) and a second mirror (M2), the most image forward folding mirror
4 (F2) deviating a beam and directing it in a direction that is parallel to a beam
5 emanating from the object plane.

1 10. An objective as in any preceding claim, wherein the real
2 image is formed with a numerical aperture of at least substantially 0.80.

1 11. An objective as in any preceding claim, wherein the real
2 image is formed with a numerical aperture of at least substantially 0.85.

1 12. An objective according to claim 2, wherein the catadioptric
2 group (G1) includes a most image forward convex mirror (M3) that receives a

3 beam after it has been twice folded and wherein the dioptric group (G2) receives a
4 beam from the convex most image forward convex mirror (M3).

1 13. An objective (100, 200) according to claim 4, wherein one
2 folding mirror (F2) and two of the mirrors (M2, M3) are upstream of the most
3 image forward lens element (E2) of the catadioptric group (G1).

1 14. An objective (100, 200) according to claim 13, wherein the
2 two mirrors (M2, M3) are more image forward than the both folding mirrors (F1,
3 F2), where one of the two mirrors (M2) receives the folded beam from a second
4 folding mirror (F2) and reflects the beam to the other of the two mirrors (M3)
5 which represents the most image forward mirror of the catadioptric group (G1).

1 15. An objective (100, 200) according to claim 2, wherein the
2 catadioptric group (G1) includes a single-pass lens element (E1) and first and
3 second folding mirrors (F1, F2) that are arranged so that a beam incident to the
4 single-pass lens element (E1) and exiting the dioptric group (G2) propagate along
5 substantially parallel axes.

1 16. An objective (100, 200) as in any preceding claim, wherein
2 a least image forward lens element (E4) of the dioptric group (G2) is a negative
3 lens and a most image forward lens element (E16) of the dioptric group (G2) is a
4 positive lens.

1 17. An objective (100, 200) according to claim 4, wherein
2 second and third mirrors (M2, M3) are arranged upstream of the two folding
3 mirrors (F1, F2) and each of the three lens elements (E1-E3), the second mirror
4 (M2) being a concave mirror that receives the folded beam from a most image

5 forward folding mirror (F2) and reflects the beam to the third convex mirror (M3)
6 which reflects light to the dioptic group (G2).

1 18. An objective (100, 200) according to claim 2, wherein the
2 catadioptric group (G1) includes two folding mirrors (F1, F2) and a reflective
3 group (M2, M3) upstream of a most image forward folding mirror (F2), the
4 reflective group (M2., M3) including one concave mirror and one convex mirror.

1 19. An objective (100, 200) according to claim 18, further
2 including a negative lens group (E2, E3) disposed between the two folding mirrors
3 (F1, F2).

1 20. An objective (100, 200) according to claim 2, wherein the
2 dioptic group (G2) includes more positive lens elements than negative lens
3 elements.

1 21. An objective (100, 200) according to any of claims 1 or 2,
2 wherein the dioptic group (G2) includes a number of lens elements (E4-E16) and
3 has a negative overall magnifying power for providing image reduction.

1 22. A photolithographic reduction projection catadioptric
2 objective (100, 200), comprising:
3 a first optical group (G1) includes an odd number of mirrors (M1-
4 M3); and
5 a second substantially refractive optical group (G2) more image
6 forward than the first optical group (G1), the second optical group (G2) including
7 a number of lens elements (E4-E16) and having a negative overall magnifying
8 power for providing image reduction;

9 wherein the first optical group (G1) has a folded geometry for
10 producing a virtual image and the second optical group (G2) receives and reduces
11 the virtual image to form an image with a numerical aperture of at least
12 substantially 0.80, wherein a beam exiting the second optical group (G2) is
13 parallel to and displaced from a beam incident to a first lens element (E1) of the
14 first optical group (G1).

1 23. An objective (100, 200) according to claim 22, wherein the
2 first optical group (G1) comprises a catadioptric group having a single pass lens
3 (E1) and a double-pass lens group (E2, E3).

1 24. An objective (100, 200) as in any of claims 22-23, wherein
2 the first optical group (G1) includes at least three mirrors (M1-M3) arranged such
3 that a second mirror (M2) having a concave surface faces a convex surface of a
4 third mirror (M3) such that the second mirror (M2) receives a beam that has been
5 folded within the first optical group (G1) and reflects the beam to the convex
6 surface of the third mirror (M3).

1 25. An objective (100, 200) according to claim 24, wherein
2 light is folded within the first optical group (G1) by first and second folding
3 mirrors (F1, F2) that are arranged so that a beam exiting the first optical group
4 (G1) and a beam incident to a first lens element (E1) of the first optical group
5 (G1) propagate along substantially parallel axes.

1 26. An objective (100, 200) according to any of claims 22-25,
2 wherein the second dioptric group (G2) includes more positive lens elements than
3 negative lens elements.

1 27. An objective (100, 200) according to any of claims 22-25,
2 wherein the first and second optical groups (G1, G2) include at least eight
3 aspheric surfaces.

1 28. An objective (100, 200) according to any of claims 22-27,
2 wherein the first optical group (G1) includes at least three mirrors (M1-M3) and
3 two folding mirrors (F1, F2) with two of the three mirrors (M2, M3) being located
4 along the optical path more image forward than the two folding mirrors (F1, F2)
5 such that one of the two mirrors (M2) receives a folded beam from the folding
6 mirror (F2) that is more image forward and reflects the beam to the other of the
7 two mirrors (M3) which represents the most image forward mirror of the
8 catadioptric group (G1).

1 29. An objective (100, 200) according to any of claims 22-28,
2 wherein the first optical group (G1) includes a single pass lens (E1) and a double-
3 pass lens group (E2, E3), the double-pass lens group (E2, E3) being disposed
4 between first and second folding mirrors (F1, F2).

1 30. A photolithographic reduction projection catadioptric
2 objective (100, 200), comprising:
3 a first optical group (G1) includes an odd number of mirrors (M1-
4 M3); and
5 a second substantially refractive optical group (G2) more image
6 forward than the first optical group (G1), the second optical group (G2) including
7 a number of lenses (E4-E16) and having a negative overall magnifying power for
8 providing image reduction;
9 wherein the first optical group (G1) has a folded off-axis field

10 geometry and provides compensative aberrative correction for the second optical
11 group (G2) which forms an image with a numerical aperture of at least
12 substantially 0.80.

1 31. A photolithographic reduction projection catadioptric
2 objective (100, 200) devoid of a beam splitter device, the objective comprising:
3 a first optical group (G1) including an odd number of at least three
4 mirrors (M1-M3) including a convex most image forward mirror (M3); and
5 a second substantially refractive optical group (G2) more image
6 forward than the first optical group (G1) for receiving a beam from the convex
7 most image forward mirror (M3) of the first group (G1) after the beam has been
8 folded along an optical path of the first optical group (G1), wherein the second
9 optical group (G2) includes a number of lens elements (E4-E16) for providing
10 image reduction.

1 32. An objective (100, 200) according to claim 31, wherein the
2 first optical group (G1) comprises a catadioptric group having at a positive lens
3 (E1) and a negative lens group (E2, E3) arranged such that the beam incident to a
4 first lens element (E1) is folded twice prior to the beam being received by a
5 reflective image forward mirror group (M2, M3) including the convex most image
6 forward mirror (M3).

1 33. An objective (100, 200) according to any of claims 31-32,
2 wherein the second optical group (G2) forms an image with a numerical aperture
3 of at least substantially 0.80.

1 34. An objective (100, 200) according to any of claims 31-32,
2 wherein the objective has a blank mass of less than 57 kg at a 22 mm x 6 mm field
3 operating at a numerical aperture of at least substantially 0.85.

1 35. An objective (100, 200) according to any of claims 31-32,
2 wherein the second optical group (G2) forms an image with a numerical aperture
3 of at least substantially 0.85.

1 36. A projection exposure apparatus comprising a light source
2 selected from the group of light sources consisting of a DUV and a VUV light
3 source, an illumination system, a reticle handling, positioning and scanning
4 system, a projection objective according to any of claims 2, 22, 30 or 31 and a
5 wafer handling, positioning and scanning system.

1 37. A microlithographic reduction projection objective (100,
2 200), comprising:
3 a first partial objective with a concave mirror (M1) and at least one
4 negative lens (NL) doubly passed by light traveling to and from the concave
5 mirror (M1);
6 an intermediate image (Imi); and
7 a second partial objective with two curved mirrors (M2, M3) and a
8 plurality of lenses (G2).

1 38. An objective (100, 200) according to claim 37, wherein the
2 second partial objective has two curved mirrors (M2, M3) forming a virtual image
3 and imageward subsequent a lens group (G2) with reduction magnification.

1 39. An objective (100, 200) according to any of claims 37 or
2 38, wherein a system aperture (AP) is located within the second partial objective
3 and only a purely refractive lens group is arranged between the system aperture
4 (AP) and an image plane (IMG).

1 40. An objective (100, 200) according to any of claims 37-39,
2 wherein the first partial objective is a catadioptric group providing the
3 intermediate image (Imi) and the second partial objective comprises an optical
4 group selected from the group of optical groups consisting of a catoptric group
5 and a catadioptric group, for providing the virtual image and the plurality of lenses
6 (G2) comprises a dioptric group providing the real image.

1 41. An objective (100, 200) according to any of claims 39-40,
2 wherein the plurality of lenses (G2) includes a positive lens group of more than 5
3 lenses (E11-E16) and a least image forward lens of the purely refractive group
4 comprises a negative lens (E10).